OUTDOOR PROTECTION FROM MOSQUITOES*

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Even in areas where mosquito control work has been systematically conducted for many years it has not been possible, with our present means and methods, completely to eradicate the mosquito. Under conditions favorable for its rapid development, such as during summers of abundant rainfall, it becomes at times a serious interference with human comfort.

When a female mosquito bites or pierces the skin to suck our blood she injects into the wound a small amount of a poisonous substance, the chemical composition of which has not been definitely established. The effect of this injected material varies with different species of mosquitoes as well as with the susceptibility of the bitten individual. While a small number of people appear to possess a certain degree of immunity, either natural or acquired, against this poison, the great majority of us, especially children, suffer from its effects. Immediately following the bite, an itching sensation is felt which may be followed by considerable swelling. The scratching induced by the irritation may cause a secondary blood infection, especially among children, leading to serious results. The irritation may be relieved by washing the swelling with any one of the following solutions: soft soap, alcohol, glycerin, iodine or borax.

Complete elimination of mosquitoes indoors can be readily accomplished by proper screening, spraying, or fumigating. On the other hand, protection from mosquito annoyance outdoors constitutes a difficult problem, the solution of which cannot always be successfully attained.

Mosquito repellents.—Various chemicals, possessing repelling properties against mosquitoes, have been recommended and commercialized. They are applied in form of lotions, ointments or powders to the exposed parts of the body. The duration of the

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protection may vary from a short time to several hours, depending on the inherent repellent properties of the chemical, thoroughness of application, species and density of the mosquito population, degree of attractiveness possessed by the individual, and atmospheric factors.

Citronella is one of the oldest mosquito repellents used either in its natural liquid state or in combination with various other compounds. One of the early formulas recommended by Dr. L. O. Howard (1923) contains the following ingredients: oil of citronella 2 ounces, spirits of camphor 2 ounces, and oil of cedar 1 ounce. This preparation can also be made in form of a salve, if desired, by mixing in enough petrolatum or similar semisolids. One thorough application may remain effective for 1 or 2 hours. Dr. Herms (1939) finds the following formula successful: citronella 3 parts, kerosene 2 parts, and coconut oil 4 parts. To this mixture is added 1 per cent carbolic acid. Within the last few years longer lasting and more efficient repellents have been synthesized, as a result of research conducted at the Federal Bureau of Entomology in Washington and at Rutgers University (Granett 1940), in cooperation with various commercial concerns. Three of these are at present widely used, namely, dimethyl phthalate, Indalone, and formula No. 612.

Though mosquito repellents are contributing a great deal toward relief from mosquito annoyance to individuals, such as night watchmen, military pickets, mosquito workers and fishermen, compelled to remain exposed for considerable lengths of time in mosquito-infested areas, their frequent application encounters many drawbacks. First, not all the repellent mixtures thus far developed repel mosquitoes from a distance. In virtually every case the mosquito has to alight, or at least come very close to the treated surface, before the chemical acts on it. Complete and thorough coverage is, therefore, necessary, otherwise untreated spots may be bitten. Second, virtually all of the repellents cause sharp smarting on delicate parts of the skin such as eyelids, face and forehead. This irritation is apt to become rather pungent and often unbearable to many sensitive individuals under warm, humid atmospheres and other conditions when copious perspiration occurs. Third, because of the solvent

properties of the repellents, a treated individual must avoid coming in contact with varnished and painted surfaces. Either paint or varnish will be partially removed, resulting in staining of clothes or any other objects incidentally touched. Fourth, the repellent does not protect a group, much less a large outdoor audience, unless each individual is treated. Fifth, continuous feel of a greasy, somewhat irritating solvent all over one's skin becomes rather unpleasant. Unless compelled by military duty or night work, few individuals will willingly submit themselves to this treatment night after night. Instead they would rather stay indoors or in a well-screened porch.

Mosquito sprays.—In view of these objectionable features, the writer became interested in developing a mosquito spray which should, with no injury to man, animals, and plants, completely free an area from adult mosquitoes where groups of people could spend a summer evening with no mosquito annoyance and with perfect body comfort. This effort coincided with another problem, that of developing a mosquito larvicide which should kill mosquito larvæ and pupæ with no injury to fish, water fowl, and aquatic plants, offering at the same time no fire hazard. Such a product was called for in residential sections, ornamental ponds, game conservation parks, and similar places where mosquito oil was objectionable. By 1931 the New Jersey Pyrethrum Mosquito Larvicide was developed and came into wide use as a substitute for oil wherever the latter meets with objections, Ginsburg (1930). The larvicide is essentially an emulsion consisting of 66 per cent kerosene, 0.5 per cent sodium lauryl sulfate as emulsifier, 0.07 per cent pyrethrins, and about 34 per cent water. The concentrated stock emulsion is mixed just before spraying with about 10 parts of clear water, which may be taken directly from the area to be sprayed.

Preliminary tests conducted during 1934 (Ginsburg 1935) indicated that spraying with this diluted larvicide might also prove effective in ridding a given area from adult mosquitoes. Further extensive experiments carried out during 1935–36 (Ginsburg 1936, 1937) by the writer in cooperation with the various County Mosquito Commissions in New Jersey have substantiated this assumption and have established a definite method of procedure for spraying.

The experiments during these three years have given us some fundamental knowledge as well as authentic information concerning the possibility and practicability of eliminating mosquito annoyance from outdoor public gatherings without in any way interfering with human comfort and activities. We have learned how to accomplish this relief without appreciable injury to plant life. These results have also thrown some light on the physical and chemical mechanism involved as well as the rôle that each ingredient of the larvicide plays in this process. From the experience thus far gained the following principles may be evolved as guides in this work.

In order successfully to eliminate adult mosquitoes from a given area outdoors, two objectives must be attained. First, all female mosquitoes resting in the grass, shrubs, and throughout the area to be treated must be killed. This is accomplished by thoroughly spraying the entire grounds before the audience gathers. Second, the influx of mosquitoes from the surroundings into the protected area must be prevented. For this purpose the spray is directed upward, as high as the pressure permits, so as to saturate the atmosphere with a fine mist of larvicide. This air-fogging may have to be repeated two or three times during the affair, depending on the species and density of mosquitoes, the flight intensity, the direction and velocity of wind, and other atmospheric factors. It should be emphasized that, for complete protection, it is just as important to kill or incapacitate all the female mosquitoes hiding in vegetation as it is to bar those in the surroundings from flying in. The spray should be applied in highly dispersed form, as a fog or mist. The finer the liquid particles, the less will be the danger of injury to plants and the longer will it remain floating in the air. The diluted larvicide must be kept thoroughly mixed during spraying.

The mechanism involved in this process is twofold, repellency and contact killing. The female mosquito when in contact with the larvicide is either killed or paralyzed to such a degree that, for an indefinite period, she can neither fly nor bite. These symptoms are brought about primarily by the pyrethrins incorporated in the larvicide. The petroleum oil acts as a carrier for the pyrethrum. It should be mentioned here that neither an aqueous

spray of pyrethrum extract nor a kerosene emulsion when applied separately gave satisfactory protection. Evidently the combination of both ingredients is necessary for adequate protection. The water in the larvicide merely serves as the outer phase in which the two toxic ingredients are dispersed by the aid of the emulsifier.

The question has been asked: What happens to the mosquitoes in the sprayed area? The following observations may offer an explanation. When tents were sprayed inside with the larvicide, some mosquitoes were found on the ground apparently dead while others remained on the canvas in a quiescent condition. When disturbed they attempted to fly but soon again attached themselves to the canvas. They remained for some time in this partly paralyzed condition and finally either dropped to the ground or flew away. These symptoms closely resemble those observed in other insects treated with pyrethrum insecticides and can, therefore, be attributed directly to the pyrethrins incorporated in the larvicide. Again, while checking the mosquito density the writer observed on several occasions that when mosquitoes reach the treated area they abruptly change their course of flight, turning back or at a right angle. This behavior suggests repellency. Evidently mosquitoes find the oil, the pyrethrum, or both combined so disagreeable that they keep away from the treated area.

DIRECTIONS FOR SPRAYING

The concentrated larvicide is first well shaken or stirred. It is then mixed with 12 parts of water (1 quart to 3 gallons) in the sprayer. This diluted mixture is ready for spraying. During the spraying operation it should be frequently shaken or stirred in order to insure uniform distribution of the larvicide.

Procedure.—Before the affair starts, the entire area, including grass, shrubs, bleachers, sheds, benches, or any other place where mosquitoes may rest during the day, is thoroughly sprayed with the diluted larvicide. This should kill all mosquitoes as well as many other insects hiding in the grass, shrubs, and other places. The next object is to prevent mosquitoes from the surroundings from coming into the protected area. For this purpose the spray is directed upward so as to saturate the atmosphere with a fine mist or fog of the larvicide. If the spray is applied against the

wind the fine mist or fog will drift with the wind throughout the area. This entire operation should be finished before the gathering takes place. Just about dusk or when the mosquitoes from the outside begin to fly in, another fogging is necessary. For this purpose the spray is applied as high as the sprayer permits and primarily on the side from which the wind is blowing. This mist in the air wards off mosquitoes from outside the treated area. If no noticeable wind prevails it may be necessary to fog all around the area, directing the spray upward so as to keep the inflying mosquitoes away. A thorough fogging about the time when the mosquitoes start coming in should be sufficient for the rest of the evening. Under very heavy infestations, where the mosquitoes are coming in large numbers, a second fogging about 9 : 30 may be necessary.

Apparatus Required.—(1) on small areas, such as backyards, porches, and private lawns, a garden sprayer, knapsack sprayer, bucket pump, or electric sprayer capable of producing a fine spray, about 10 or 15 feet high, may be used with success.

(2) For spraying large areas, such as picnic grounds, stadiums, and open air theaters, a power sprayer capable of developing a pressure of 200 pounds or more per square inch and equipped with a spray gun is necessary. The larvicide has been found most efficient in protecting outdoor audiences on comparatively large areas where power sprayers can be used.

Precautions.—Before attempting to treat an area, one should make a thorough survey in order to ascertain the following points: sources of mosquitoes; possible mosquito resting places; direction of wind; type of vegetation present; water supply for mixing the larvicide; kind of spraying outfit necessary; nature of gatherings; and any difficulties that may be anticipated during the spraying operation. This information should enable the operator to plan his method of procedure.

PRESENT STATUS OF THE NEW JERSEY PYRETHRUM MOSQUITO LARVICIDE

Since this spray was introduced, numerous outdoor evening concerts, carnivals, church parties, community gatherings, and lawn parties have been fully protected from mosquitoes either directly by the County Mosquito Commissions at a nominal cost,

or indirectly through their assistance, guidance, and advice. The number of persons present on these occasions varied from small groups to many thousands. Records show that in several instances some 20,000* persons in one gathering have enjoyed an open air evening concert with no mosquito discomfort as a result of spraying the stadium where the affair was held. When the larvicide was sprayed as directed, no injury has resulted to grass, shrubs, trees, ornamental plants or aquatic plants. Up to and including 1942, its use increased with each successive season.

Prior to 1934 most of the pyrethrum used in this country came from Japan, and small amounts from Dalmatia and the Kenya Colony in British East Africa. By 1939 the picture was reversed; most of our pyrethrum was imported from Kenya and very little from Japan. When World War II broke out, cultivation of pyrethrum in the British possessions, for various reasons, decreased. Shipping shortage and submarine losses still further curtailed the flow of pyrethrum flowers to this country. After Pearl Harbor, practically all the available and potential supplies of pyrethrum were taken over by the United States Government for army use. At present the War Production Board does not allow the use of pyrethrum for preparing the larvicide. Thus, the excellent record of this newly developed method for temporary relief from biting female mosquitoes has been suddenly terminated for the duration or until enough pyrethrum becomes available to supply a surplus, above the amount necessary for our armed forces.

Intensive testing is now being conducted with various other chemicals as possible substitutes for pyrethrum. At this date, however, none has proved equal to pyrethrum from the standpoints of effectiveness against the mosquito and of safety to man, animals, and plants.

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